

WHAT IS CLAIMED IS

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1. A distributed Bragg reflector,  
comprising:

a first semiconductor layer having a first,  
larger refractive index;

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a second semiconductor layer having a  
second, lower refractive index,

said first and second semiconductor layers  
being stacked alternately,

15 a material layer having a refractive index  
intermediate between said first and second refractive  
indices,

said distributed Bragg reflector being  
tuned to a wavelength of 1.1  $\mu\text{m}$  or longer,

20 wherein there is provided a material layer  
having a refractive index intermediate between said  
first refractive index and said second refractive  
index,

said material layer having a thickness  
equal to or larger than 5 nm but equal to or smaller  
25 than 50 nm.

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2. A distributed Bragg reflector as claimed  
in claim 1, wherein said material layer has a  
thickness equal to or larger than 20 nm.

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3. A distributed Bragg reflector as claimed  
in claim 1, wherein said material layer has a  
10 thickness equal to or larger than 30 nm.

15 4. A distributed Bragg reflector as claimed  
in claim 2, wherein said first and second  
semiconductor layers are formed of any of AlAs, GaAs  
and AlGaAs, and wherein there is a difference of Al  
content of less than 80% between said first  
20 semiconductor layer and said second semiconductor  
layer.

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5. A distributed Bragg reflector as claimed  
in claim 3, wherein said first semiconductor layer  
and said second semiconductor layer are formed of any  
of AlAs, GaAs and AlGaAs, and wherein there is a  
5 difference of Al content of 80% or more between said  
first semiconductor layer and said second  
semiconductor layer.

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6. A distributed Bragg reflector,  
comprising:

15 a first semiconductor layer having a first,  
larger refractive index;

a second semiconductor layer having a  
second, lower refractive index,

said first and second semiconductor layers  
being stacked alternately,

20 a material layer having a refractive index  
intermediate between said first and second refractive  
indices,

said distributed Bragg reflector being  
tuned to a wavelength of 1.1  $\mu\text{m}$  or longer,

25 wherein there is provided a material layer

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having a refractive index intermediate between said first refractive index and said second refractive index,

said material layer having a thickness  
5 smaller than  $(50\lambda - 15)$  [nm] where  $\lambda$  is a tuned wavelength of the distributed Bragg reflector.

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7. A distributed Bragg reflector as claimed in claim 6, wherein said material layer has a thickness of 20 nm or more.

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8. A distributed Bragg reflector as claimed in claim 6, wherein said material layer has a  
20 thickness of 30 nm or more.

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9. A distributed Bragg reflector,

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comprising:

a first semiconductor layer having a first, smaller bandgap;

a second semiconductor layer having a  
5 second, larger bandgap,

said first and second semiconductor layers being stacked alternately,

a material layer having a bandgap intermediate between said first and second bandgaps,  
10 provided between said first and second semiconductor layer,

said material layer changing a valence band energy thereof in a thickness direction from said first semiconductor layer to said second  
15 semiconductor layer,

said material layer comprising a first layer adjacent to said first semiconductor layer and a second layer adjacent to said second semiconductor layer,

20 said first layer and second layer having first and second rates of compositional change such that said first rate being larger than said second rate.

10. A distributed Bragg reflector as  
claimed in claim 9, wherein said intermediate layer  
changes said valence band energy continuously and  
gradually from said first semiconductor layer to said  
5 second semiconductor layer.

10 11. A distributed Bragg reflector as  
claimed in claim 9, wherein said intermediate layer  
changes said valence band energy stepwise from said  
first semiconductor layer to said second  
semiconductor layer.

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12. A distributed Bragg reflector as  
20 claimed in claim 9, wherein said intermediate layer  
comprises a layer in which said valence band energy  
changes continuously and a layer in which said  
valence band energy changes stepwise.

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13. A distributed Bragg reflector as  
claimed in claim 9, wherein said first and second  
layers have respective first and second thicknesses,  
such that said first thickness is smaller than said  
5 second thickness.

10 14. A distributed Bragg reflector as  
claimed in claim 9, wherein there is a stepped change  
of valence band energy at an interface between said  
first semiconductor layer and said material layer.

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15. A distributed Bragg reflector as  
claimed in claim 9, wherein said first and second  
20 semiconductor layers comprise a material of AlGaAs  
system.

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16. A distributed Bragg reflector as claimed in claim 9, wherein said first and second semiconductor layers comprise a material of AlGaAsP system.

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17. A distributed Bragg reflector as  
10 claimed in claim 9, wherein said first and second semiconductor layers and said intermediate layer have a carrier density of  $5 \times 10^{17} \text{cm}^{-3} - 2 \times 10^{18} \text{cm}^{-3}$ , and wherein said intermediate layer has a thickness in the range of 5 - 40 nm, and wherein said intermediate  
15 layer is characterized by an average change rate of Al content in the range of 0.02 - 0.05 nm<sup>-1</sup>.

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18. A surface-emission laser diode,  
comprising:

an active layer; and

a resonator cooperating with said active  
25 layer, said active layer comprising upper and lower

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reflectors disposed above and below said active layer,  
at least one of said upper and lower  
reflectors comprising a distributed Bragg reflector,  
comprising:

5 a first semiconductor layer having a first,  
larger refractive index;

a second semiconductor layer having a  
second, lower refractive index,

said first and second semiconductor layers  
10 being stacked alternately,

a material layer having a refractive index  
intermediate between said first and second refractive  
indices,

said distributed Bragg reflector being  
15 tuned to a wavelength of  $1.1 \mu\text{m}$  or longer,

wherein there is provided a material layer  
having a refractive index intermediate between said  
first refractive index and said second refractive  
index,

20 said material layer having a thickness  
equal to or larger than 5 nm but equal to or smaller  
than 50 nm.

19. A surface-emission laser diode as  
claimed in claim 18, wherein said material layer has  
a thickness equal to or larger than 20 nm.

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20. A surface-emission laser diode as  
claimed in claim 18, wherein said material layer has  
10 a thickness equal to or larger than 30 nm.

15 21. A surface-emission laser diode as  
claimed in claim 19, wherein said first and second  
semiconductor layers are formed of any of AlAs, GaAs  
and AlGaAs, and wherein there is a difference of Al  
content of less than 80% between said first  
20 semiconductor layer and said second semiconductor  
layer.

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22. A surface-emission laser diode as  
claimed in claim 20, wherein said first semiconductor  
layer and said second semiconductor layer are formed  
of any of AlAs, GaAs and AlGaAs, and wherein there is  
5 a difference of Al content of 80% or more between  
said first semiconductor layer and said second  
semiconductor layer.

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23. A surface-emission laser diode as  
claimed in claim 18, wherein said active layer is  
formed of any of a GaNAs layer, a GaInAs layer, a  
15 GaInNAs layer, a GaAsSb layer, a GaInAsSb layer, and  
a GaInNAsSb layer.

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24. A surface-emission laser diode,  
comprising:

an active layer; and

a resonator cooperating with said active  
layer, said active layer comprising upper and lower  
25 reflectors disposed above and below said active layer,

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at least one of said upper and lower reflectors comprising a distributed Bragg reflector, comprising:

a first semiconductor layer having a first,  
5 larger refractive index;

a second semiconductor layer having a second, lower refractive index,

said first and second semiconductor layers being stacked alternately,

10 a material layer having a refractive index intermediate between said first and second refractive indices,

said distributed Bragg reflector being tuned to a wavelength of  $1.1 \mu\text{m}$  or longer,

15 wherein there is provided a material layer having a refractive index intermediate between said first refractive index and said second refractive index,

said material layer having a thickness  
20 smaller than  $(50\lambda - 15)$  [nm] where  $\lambda$  is a tuned wavelength of the distributed Bragg reflector.

25. A surface-emission laser diode as  
claimed in claim 24, wherein said material layer has  
a thickness of 20 nm or more.

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26. A surface-emission laser diode as  
claimed in claim 24, wherein said material layer has  
10 a thickness of 30 nm or more.

15 27. A surface-emission laser diode as  
claimed in claim 24, wherein said active layer is  
formed of any of a GaNAs layer, a GaInAs layer, a  
GaInNAS layer, a GaAsSb layer, a GaInAsSb layer, and  
a GaInNASb layer.

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28. A surface-emission laser diode,  
25 comprising:

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an active layer; and

a resonator cooperating with said active layer, said active layer comprising upper and lower reflectors disposed above and below said active layer,

5 at least one of said upper and lower reflectors comprising a distributed Bragg reflector, comprising:

a first semiconductor layer having a first, smaller bandgap;

10 a second semiconductor layer having a second, larger bandgap,

said first and second semiconductor layers being stacked alternately,

a material layer having a bandgap  
15 intermediate between said first and second bandgaps, provided between said first and second semiconductor layer,

said material layer changing a valence band energy thereof in a thickness direction from said  
20 first semiconductor layer to said second semiconductor layer,

said material layer comprising a first layer adjacent to said first semiconductor layer and a second layer adjacent to said second semiconductor  
25 layer,

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said first layer and second layer having first and second rates of compositional change such that said first rate being larger than said second rate.

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29. A surface-emission laser diode as  
10 claimed in claim 28, wherein said intermediate layer changes said valence band energy continuously and gradually from said first semiconductor layer to said second semiconductor layer.

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30. A surface-emission laser diode as  
claimed in claim 28, wherein said intermediate layer  
20 changes said valence band energy stepwise from said first semiconductor layer to said second semiconductor layer.

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31. A surface-emission laser diode as  
claimed in claim 28, wherein said intermediate layer  
comprises a layer in which said valence band energy  
changes continuously and a layer in which said  
5 valence band energy changes stepwise.

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32. A surface-emission laser diode as  
claimed in claim 28, wherein said first and second  
layers have respective first and second thicknesses,  
such that said first thickness is smaller than said  
15 second thickness.

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33. A surface-emission laser diode as  
claimed in claim 28, wherein there is a stepped  
change of valence band energy at an interface between  
said first semiconductor layer and said material  
layer.

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34. A surface-emission laser diode as claimed in claim 28, wherein said first and second semiconductor layers comprise a material of AlGaAs system.

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35. A surface-emission laser diode as claimed in claim 28, wherein said first and second semiconductor layers comprise a material of AlGaAsP system.

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36. A surface-emission laser diode as claimed in claim 28, wherein said first and second semiconductor layers and said intermediate layer have a carrier density of  $5 \times 10^{17} \text{cm}^{-3} - 2 \times 10^{18} \text{cm}^{-3}$ , and wherein said intermediate layer has a thickness in the range of 5 - 40 nm, and wherein said intermediate layer is characterized by an average change rate of Al content in the range of 0.02 - 0.05 nm<sup>-1</sup>.

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37. A laser diode array, comprising:

5           a substrate; and

          a plurality of surface-emission laser diodes formed commonly on said substrate, each of said plurality of surface-emission laser diodes comprising:

10           an active layer; and

          a resonator cooperating with said active layer, said active layer comprising upper and lower reflectors disposed above and below said active layer, at least one of said upper and lower

15   reflectors comprising a distributed Bragg reflector, comprising:

          a first semiconductor layer having a first, larger refractive index;

          a second semiconductor layer having a

20   second, lower refractive index,

          said first and second semiconductor layers being stacked alternately,

          a material layer having a refractive index intermediate between said first and second refractive

25   indices,

said distributed Bragg reflector being  
tuned to a wavelength of  $1.1 \mu\text{m}$  or longer,

wherein there is provided a material layer  
having a refractive index intermediate between said  
5 first refractive index and said second refractive  
index,

said material layer having a thickness  
equal to or larger than 5 nm but equal to or smaller  
than 50 nm.

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38. A laser diode array, comprising:

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a substrate; and

a plurality of surface-emission laser  
diodes formed commonly on said substrate, each of  
said surface emission laser diodes comprising:

an active layer; and

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a resonator cooperating with said active  
layer, said active layer comprising upper and lower  
reflectors disposed above and below said active layer,  
at least one of said upper and lower

reflectors comprising a distributed Bragg reflector,

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comprising:

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a first semiconductor layer having a first, larger refractive index;

a second semiconductor layer having a second, lower refractive index,

5           said first and second semiconductor layers being stacked alternately,

a material layer having a refractive index intermediate between said first and second refractive indices,

10           said distributed Bragg reflector being tuned to a wavelength of  $1.1 \mu\text{m}$  or longer,

          wherein there is provided a material layer having a refractive index intermediate between said first refractive index and said second refractive index,

15           said material layer having a thickness smaller than  $(50\lambda - 15)$  [nm] where  $\lambda$  is a tuned wavelength of the distributed Bragg reflector.

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39. A surface-emission laser diode array, comprising:

25           a substrate; and

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a plurality of laser diodes, each of said surface-emission laser diodes, comprising:

an active layer; and

a resonator cooperating with said active  
5 layer, said active layer comprising upper and lower reflectors disposed above and below said active layer, at least one of said upper and lower reflectors comprising a distributed Bragg reflector, comprising:

10 a first semiconductor layer having a first, smaller bandgap;

a second semiconductor layer having a second, larger bandgap,

said first and second semiconductor layers  
15 being stacked alternately,

a material layer having a bandgap intermediate between said first and second bandgaps, provided between said first and second semiconductor layer,

20 said material layer changing a valence band energy thereof in a thickness direction from said first semiconductor layer to said second semiconductor layer,

said material layer comprising a first  
25 layer adjacent to said first semiconductor layer and

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a second layer adjacent to said second semiconductor layer,

said first layer and second layer having first and second rates of compositional change such that said first rate being larger than said second rate.

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40. An optical interconnection system, comprising:

a surface-emission laser diode; and  
an optical transmission path coupled  
15 optically to said surface-emission laser diode,  
said surface-emission laser diode

comprising:

an active layer; and  
a resonator cooperating with said active  
20 layer, said active layer comprising upper and lower  
reflectors disposed above and below said active layer,  
at least one of said upper and lower  
reflectors comprising a distributed Bragg reflector,  
comprising:

25 a first semiconductor layer having a first,

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larger refractive index;

a second semiconductor layer having a second, lower refractive index,

said first and second semiconductor layers  
5 being stacked alternately,

a material layer having a refractive index intermediate between said first and second refractive indices,

said distributed Bragg reflector being  
10 tuned to a wavelength of 1.1  $\mu\text{m}$  or longer,

wherein there is provided a material layer having a refractive index intermediate between said first refractive index and said second refractive index,

15 said material layer having a thickness equal to or larger than 5 nm but equal to or smaller than 50 nm.

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41. An optical interconnection system, comprising:

a surface-emission laser diode; and  
25 an optical transmission path coupled

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optically to said surface-emission laser diode,  
said surface-emission laser diode  
comprising:

an active layer; and

5 a resonator cooperating with said active  
layer, said active layer comprising upper and lower  
reflectors disposed above and below said active layer,  
at least one of said upper and lower  
reflectors comprising a distributed Bragg reflector,  
10 comprising:

a first semiconductor layer having a first,  
larger refractive index;

a second semiconductor layer having a  
second, lower refractive index,

15 said first and second semiconductor layers  
being stacked alternately,

a material layer having a refractive index  
intermediate between said first and second refractive  
indices,

20 said distributed Bragg reflector being  
tuned to a wavelength of  $1.1 \mu\text{m}$  or longer,

wherein there is provided a material layer  
having a refractive index intermediate between said  
first refractive index and said second refractive  
25 index,

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said material layer having a thickness smaller than  $(50\lambda-15)$  [nm] where  $\lambda$  is a tuned wavelength of the distributed Bragg reflector.

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42. An optical interconnection system, comprising:

- 10 a surface-emission laser diode; and  
an optical transmission path coupled optically to said surface-emission laser diode,  
said surface-emission laser diode comprising:
- 15 an active layer; and  
a resonator cooperating with said active layer, said active layer comprising upper and lower reflectors disposed above and below said active layer,  
at least one of said upper and lower  
20 reflectors comprising a distributed Bragg reflector,  
comprising:
- a first semiconductor layer having a first, smaller bandgap;  
a second semiconductor layer having a  
25 second, larger bandgap,

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said first and second semiconductor layers  
being stacked alternately,

a material layer having a bandgap  
intermediate between said first and second bandgaps,  
5 provided between said first and second semiconductor  
layer,

said material layer changing a valence band  
energy thereof in a thickness direction from said  
first semiconductor layer to said second  
10 semiconductor layer,

said material layer comprising a first  
layer adjacent to said first semiconductor layer and  
a second layer adjacent to said second semiconductor  
layer,

15 said first layer and second layer having  
first and second rates of compositional change such  
that said first rate being larger than said second  
rate.

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43. An optical interconnection system,  
comprising:

25 a surface-emission laser diode array

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comprising a substrate and a plurality of surface-emission laser diodes provided commonly on said substrate; and

an optical transmission path coupled  
5 optically to each of said plurality of surface-emission laser diodes,

each of said plurality of surface-emission laser diodes comprising:

an active layer; and

10 a resonator cooperating with said active layer, said active layer comprising upper and lower reflectors disposed above and below said active layer,

at least one of said upper and lower reflectors comprising a distributed Bragg reflector,

15 comprising:

a first semiconductor layer having a first, larger refractive index;

a second semiconductor layer having a second, lower refractive index,

20 said first and second semiconductor layers being stacked alternately,

a material layer having a refractive index intermediate between said first and second refractive indices,

25 said distributed Bragg reflector being

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tuned to a wavelength of 1.1  $\mu\text{m}$  or longer,

wherein there is provided a material layer  
having a refractive index intermediate between said  
first refractive index and said second refractive  
5 index,

said material layer having a thickness  
equal to or larger than 5 nm but equal to or smaller  
than 50 nm.

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44. An optical interconnection system,  
comprising:

15 a surface-emission laser diode array  
comprising a substrate and a plurality of surface-  
emission laser diodes formed commonly on said  
substrate; and

an optical transmission path coupled  
20 optically to each of said plurality of surface-  
emission laser diodes,

each of said surface-emission laser diodes  
comprising:

an active layer; and  
25 a resonator cooperating with said active

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layer, said active layer comprising upper and lower reflectors disposed above and below said active layer, at least one of said upper and lower reflectors comprising a distributed Bragg reflector,

5 comprising:

a first semiconductor layer having a first, larger refractive index;

a second semiconductor layer having a second, lower refractive index,

10 said first and second semiconductor layers being stacked alternately,

a material layer having a refractive index intermediate between said first and second refractive indices,

15 said distributed Bragg reflector being tuned to a wavelength of  $1.1 \mu\text{m}$  or longer,

wherein there is provided a material layer having a refractive index intermediate between said first refractive index and said second refractive index,

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said material layer having a thickness smaller than  $(50\lambda - 15)$  [nm] where  $\lambda$  is a tuned wavelength of the distributed Bragg reflector.

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45. An optical interconnection system,  
comprising:

a surface-emission laser diode array  
comprising a plurality of surface-emission laser  
5 diodes; and

an optical transmission path coupled  
optically to each of said plurality of surface-  
emission laser diodes,

each of said surface-emission laser diodes  
10 comprising:

an active layer; and

a resonator cooperating with said active  
layer, said active layer comprising upper and lower  
reflectors disposed above and below said active layer,  
15 at least one of said upper and lower  
reflectors comprising a distributed Bragg reflector,  
comprising:

a first semiconductor layer having a first,  
smaller bandgap;

20 a second semiconductor layer having a  
second, larger bandgap,

said first and second semiconductor layers  
being stacked alternately,

a material layer having a bandgap  
25 intermediate between said first and second bandgaps,

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provided between said first and second semiconductor layer,

said material layer changing a valence band energy thereof in a thickness direction from said first semiconductor layer to said second semiconductor layer,

said material layer comprising a first layer adjacent to said first semiconductor layer and a second layer adjacent to said second semiconductor layer,

said first layer and second layer having first and second rates of compositional change such that said first rate being larger than said second rate.

46. An optical telecommunication system, comprising:

a surface-emission laser diode; and  
an optical transmission path coupled optically to said surface-emission laser diode,  
said surface-emission laser diode

comprising:

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an active layer; and

a resonator cooperating with said active layer, said active layer comprising upper and lower reflectors disposed above and below said active layer,

5 at least one of said upper and lower reflectors comprising a distributed Bragg reflector, comprising:

a first semiconductor layer having a first, larger refractive index;

10 a second semiconductor layer having a second, lower refractive index,

said first and second semiconductor layers being stacked alternately,

a material layer having a refractive index  
15 intermediate between said first and second refractive indices,

said distributed Bragg reflector being tuned to a wavelength of 1.1  $\mu\text{m}$  or longer,

wherein there is provided a material layer  
20 having a refractive index intermediate between said first refractive index and said second refractive index,

said material layer having a thickness equal to or larger than 5 nm but equal to or smaller  
25 than 50 nm.

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47. An optical telecommunication system,  
comprising:

a surface-emission laser diode; and  
an optical transmission path coupled  
5 optically to said surface-emission laser diode,  
said surface-emission laser diode

comprising:

an active layer; and  
a resonator cooperating with said active  
10 layer, said active layer comprising upper and lower  
reflectors disposed above and below said active layer,  
at least one of said upper and lower  
reflectors comprising a distributed Bragg reflector,  
comprising:

15 a first semiconductor layer having a first,  
larger refractive index;

a second semiconductor layer having a  
second, lower refractive index,

said first and second semiconductor layers  
20 being stacked alternately,

a material layer having a refractive index  
intermediate between said first and second refractive  
indices,

said distributed Bragg reflector being  
25 tuned to a wavelength of 1.1  $\mu$ m or longer,

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wherein there is provided a material layer having a refractive index intermediate between said first refractive index and said second refractive index,

5           said material layer having a thickness smaller than  $(50\lambda - 15)$  [nm] where  $\lambda$  is a tuned wavelength of the distributed Bragg reflector.

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48. An optical telecommunication system, comprising:

15           a surface-emission laser diode; and  
          an optical transmission path coupled optically to said surface-emission laser diode,  
          said surface-emission laser diode

comprising:

          an active layer; and  
20           a resonator cooperating with said active layer, said active layer comprising upper and lower reflectors disposed above and below said active layer,  
          at least one of said upper and lower reflectors comprising a distributed Bragg reflector,  
25           comprising:

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a first semiconductor layer having a first, smaller bandgap;

a second semiconductor layer having a second, larger bandgap,

5           said first and second semiconductor layers being stacked alternately,

          a material layer having a bandgap intermediate between said first and second bandgaps, provided between said first and second semiconductor  
10   layer,

          said material layer changing a valence band energy thereof in a thickness direction from said first semiconductor layer to said second semiconductor layer,

15           said material layer comprising a first layer adjacent to said first semiconductor layer and a second layer adjacent to said second semiconductor layer,

          said first layer and second layer having  
20   first and second rates of compositional change such that said first rate being larger than said second rate.

49. An optical telecommunication system,  
comprising:

a surface-emission laser diode array  
5 comprising a substrate and a plurality of surface-  
emission laser diodes provided commonly on said  
substrate; and

an optical transmission path coupled  
optically to each of said plurality of surface-  
10 emission laser diodes,

each of said plurality of surface-emission  
laser diodes comprising:

an active layer; and

a resonator cooperating with said active  
15 layer, said active layer comprising upper and lower  
reflectors disposed above and below said active layer,  
at least one of said upper and lower  
reflectors comprising a distributed Bragg reflector,  
comprising:

20 a first semiconductor layer having a first,  
larger refractive index;

a second semiconductor layer having a  
second, lower refractive index,

said first and second semiconductor layers  
25 being stacked alternately,

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a material layer having a refractive index intermediate between said first and second refractive indices,

said distributed Bragg reflector being  
5 tuned to a wavelength of  $1.1 \mu\text{m}$  or longer,

wherein there is provided a material layer having a refractive index intermediate between said first refractive index and said second refractive index,

10 said material layer having a thickness equal to or larger than 5 nm but equal to or smaller than 50 nm.

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50. An optical telecommunication system, comprising:

a surface-emission laser diode array  
20 comprising a substrate and a plurality of surface-emission laser diodes formed commonly on said substrate; and

an optical transmission path coupled optically to each of said plurality of surface-  
25 emission laser diodes,

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each of said surface-emission laser diodes  
comprising:

an active layer; and

a resonator cooperating with said active  
5 layer, said active layer comprising upper and lower  
reflectors disposed above and below said active layer,

at least one of said upper and lower  
reflectors comprising a distributed Bragg reflector,  
comprising:

10 a first semiconductor layer having a first,  
larger refractive index;

a second semiconductor layer having a  
second, lower refractive index,

said first and second semiconductor layers  
15 being stacked alternately,

a material layer having a refractive index  
intermediate between said first and second refractive  
indices,

said distributed Bragg reflector being  
20 tuned to a wavelength of 1.1  $\mu\text{m}$  or longer,

wherein there is provided a material layer  
having a refractive index intermediate between said  
first refractive index and said second refractive  
index,

25 said material layer having a thickness

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smaller than  $(50\lambda-15)$  [nm] where  $\lambda$  is a tuned wavelength of the distributed Bragg reflector.

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51..An optical telecommunication system,  
comprising:

a surface-emission laser diode array  
10 comprising a plurality of surface-emission laser  
diodes; and

an optical transmission path coupled  
optically to each of said plurality of surface-  
emission laser diodes,

15 each of said surface-emission laser diodes  
comprising:

an active layer; and

a resonator cooperating with said active  
layer, said active layer comprising upper and lower  
20 reflectors disposed above and below said active layer,

at least one of said upper and lower  
reflectors comprising a distributed Bragg reflector,  
comprising:

a first semiconductor layer having a first,  
25 smaller bandgap;

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a second semiconductor layer having a  
second, larger bandgap,

said first and second semiconductor layers  
being stacked alternately,

5 a material layer having a bandgap  
intermediate between said first and second bandgaps,  
provided between said first and second semiconductor  
layer,

said material layer changing a valence band  
10 energy thereof in a thickness direction from said  
first semiconductor layer to said second  
semiconductor layer,

said material layer comprising a first  
layer adjacent to said first semiconductor layer and  
15 a second layer adjacent to said second semiconductor  
layer,

said first layer and second layer having  
first and second rates of compositional change such  
that said first rate being larger than said second  
20 rate.

25 52. An optical transmission/reception

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system, comprising:

an optical source formed of a surface-emission laser diode device, said surface-emission laser diode comprising: an active layer of any of a layer containing Ga, In, N and As as major constituent elements thereof and a layer containing Ga, In and As as major constituent elements thereof, said active layer producing optical radiation with a laser oscillation wavelength of  $1.1 - 1.7 \mu\text{m}$ ; and a cavity structure comprising a pair of reflectors provided above and below said active layer, each of said reflectors forming a semiconductor distributed Bragg reflector reflecting optical radiation having a wavelength of  $1.1 \mu\text{m}$  or more and comprising an alternate and repetitive stacking of a first material layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x \leq 1$ ) and a second material layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ), wherein there is provided a hetero spike buffer layer between said first material layer and said second material layer, said hetero spike buffer layer having a refractive index intermediate between a refractive index of said first material layer and a refractive index of said second material layer, said hetero spike buffer layer having a composition represented as  $\text{Al}_z\text{Ga}_{1-z}\text{As}$  ( $0 \leq y < z < x \leq 1$ ) and a thickness of 20 - 50 nm;

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an optical fiber transmission path having  
an end coupled optically to said optical source; and  
a photodetection unit coupled to the other  
end of said optical fiber transmission path,

5           said optical fiber transmission path being  
bent between a point A, in which said optical source  
is provided, and a point B, in which said  
photodetection unit is provided, such that there is  
no localized angle formed in said optical fiber  
10   transmission path.

15           53. An optical transmission/reception  
system, comprising:

an optical source formed of a surface-  
emission laser diode device, said surface-emission  
laser diode comprising: an active layer of any of a  
20   layer containing Ga, In, N and As as major  
constituent elements thereof and a layer containing  
Ga, In and As as major constituent elements thereof,  
said active layer producing optical radiation with a  
laser oscillation wavelength of 1.1 - 1.7  $\mu\text{m}$ ; and a  
25   cavity structure comprising a pair of reflectors

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provided above and below said active layer, each of  
said reflectors forming a semiconductor distributed  
Bragg reflector reflecting optical radiation having a  
wavelength of  $1.1\mu\text{m}$  or more and comprising an  
5 alternate and repetitive stacking of a first material  
layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x \leq 1$ ) and a second material  
layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ), wherein there is  
provided a hetero spike buffer layer between said  
first material layer and said second material layer,  
10 said hetero spike buffer layer having a refractive  
index intermediate between a refractive index of said  
first material layer and a refractive index of said  
second material layer, said hetero spike buffer layer  
having a composition represented as  $\text{Al}_z\text{Ga}_{1-z}\text{As}$  ( $0 \leq$   
15  $y < z < x \leq 1$ ) and a thickness of 20 - 50 nm;

an optical fiber transmission path having  
an end coupled to said optical source;

a photodetection unit coupled to another  
end of said optical fiber transmission path; and

20 a mirror provided between a point A, in  
which said optical source is provided, and a point B,  
in which said photodetection unit is provided, said  
mirror changing a direction of propagation of an  
optical signal transmitted through said optical fiber  
25 transmission path.

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5           54. An optical transmission/reception  
system for use in an apparatus, comprising:  
an apparatus body;  
a surface-emission laser diode device  
provided in said apparatus body as a laser optical  
10 source, said laser optical source producing an  
optical signal;  
a photodetection unit provided in said  
apparatus body, said photodetection unit receiving  
said optical signal;  
15 a cover member covering a light emitting  
part of said laser optical source; and  
another cover member covering a  
photodetection part of said photodetection unit,  
said surface-emission laser diode  
20 comprising: an active layer of any of a layer  
containing Ga, In, N and As as major constituent  
elements thereof and a layer containing Ga, In and As  
as major constituent elements thereof, said active  
layer producing optical radiation with a laser  
25 oscillation wavelength of 1.1 - 1.7  $\mu$ m; and a cavity

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structure comprising a pair of reflectors provided  
above and below said active layer, each of said  
reflectors forming a semiconductor distributed Bragg  
reflector reflecting optical radiation having a  
5 wavelength of  $1.1\mu\text{m}$  or more and comprising an  
alternate and repetitive stacking of a first material  
layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x \leq 1$ ) and a second material  
layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ), wherein there is  
provided a hetero spike buffer layer between said  
10 first material layer and said second material layer,  
said hetero spike buffer layer having a refractive  
index intermediate between a refractive index of said  
first material layer and a refractive index of said  
second material layer, said hetero spike buffer layer  
15 having a composition represented as  $\text{Al}_z\text{Ga}_{1-z}\text{As}$  ( $0 \leq$   
 $y < z < x \leq 1$ ) and a thickness of 20 - 50 nm.

20

55. An optical telecommunication system,  
comprising:

- a laser diode;
- a first optical fiber coupled optically to
- 25 said laser diode, said first optical fiber being

injected with a laser beam produced by said laser diode;

a second optical fiber coupled optically to said first optical fiber, said second optical fiber  
5 being injected with an optical signal transmitted through said first optical fiber;

a third optical fiber coupled optically to said second optical fiber, said third optical fiber being injected with an optical signal transmitted  
10 through said second optical fiber; and

a photodetector coupled optically to said third optical fiber, said photodetector detecting an optical signal transmitted through said third optical fiber,

15 said laser diode comprising a surface-emission laser diode chip and comprising: an active layer of any of a layer containing Ga, In, N and As as major constituent elements thereof and a layer containing Ga, In and As as major constituent  
20 elements thereof, said active layer producing optical radiation with a laser oscillation wavelength of 1.1 - 1.7  $\mu\text{m}$ ; and a cavity structure comprising a pair of reflectors provided above and below said active layer, each of said reflectors forming a  
25 semiconductor distributed Bragg reflector reflecting

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optical radiation having a wavelength of  $1.1\mu\text{m}$  or more and comprising an alternate and repetitive stacking of a first material layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x \leq 1$ ) and a second material layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ), wherein there is provided a hetero spike buffer layer between said first material layer and said second material layer, said hetero spike buffer layer having a refractive index intermediate between a refractive index of said first material layer and a refractive index of said second material layer, said hetero spike buffer layer having a composition represented as  $\text{Al}_z\text{Ga}_{1-z}\text{As}$  ( $0 \leq y < z < x \leq 1$ ) and a thickness of 20 - 50 nm.

15

56. An optical telecommunication system, comprising:

20 a laser diode;

a first optical fiber coupled optically to said laser diode, said first optical fiber being injected with a laser beam produced by said laser diode;

25 a second optical fiber coupled optically to

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said first optical fiber, said second optical fiber being injected with an optical signal transmitted through said first optical fiber;

a third optical fiber coupled optically to  
5 said second optical fiber, said third optical fiber being injected with an optical signal transmitted through said second optical fiber,

10 said laser diode comprising a surface-emission laser diode chip and comprising: an active layer of any of a layer containing Ga, In, N and As as major constituent elements thereof and a layer containing Ga, In and As as major constituent elements thereof, said active layer producing optical radiation with a laser oscillation wavelength of 1.1  
15 - 1.7  $\mu\text{m}$ ; and a cavity structure comprising a pair of reflectors provided above and below said active layer, each of said reflectors forming a semiconductor distributed Bragg reflector reflecting optical radiation having a wavelength of 1.1  $\mu\text{m}$  or  
20 more and comprising an alternate and repetitive stacking of a first material layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x \leq 1$ ) and a second material layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ), wherein there is provided a hetero spike buffer layer between said first material layer and said  
25 second material layer, said hetero spike buffer layer

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having a refractive index intermediate between a refractive index of said first material layer and a refractive index of said second material layer, said hetero spike buffer layer having a composition  
5 represented as  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ) and a thickness of 20 - 50 nm,

said first optical fiber having a length of 1 mm or more.

10

57. An optical telecommunication system comprising:

15 a laser diode; and

an optical transmission path coupled optically to said laser diode,

said laser diode comprising a surface-emission laser diode chip and comprising: an active  
20 layer of any of a layer containing Ga, In, N and As as major constituent elements thereof and a layer containing Ga, In and As as major constituent elements thereof, said active layer producing optical radiation with a laser oscillation wavelength of 1.1  
25 - 1.7  $\mu\text{m}$ ; and a cavity structure comprising a pair

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of reflectors provided above and below said active layer, each of said reflectors forming a semiconductor distributed Bragg reflector reflecting optical radiation having a wavelength of  $1.1\mu\text{m}$  or more and comprising an alternate and repetitive stacking of a first material layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x \leq 1$ ) and a second material layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ), wherein there is provided a hetero spike buffer layer between said first material layer and said second material layer, said hetero spike buffer layer having a refractive index intermediate between a refractive index of said first material layer and a refractive index of said second material layer, said hetero spike buffer layer having a composition represented as  $\text{Al}_z\text{Ga}_{1-z}\text{As}$  ( $0 \leq y < z < x \leq 1$ ) and a thickness of 20 - 50 nm,

said optical transmission path comprising an optical fiber having a length  $L$ , said optical fiber including a core having a diameter  $D$  and a clad, wherein there holds a relationship  $10^5 \leq L/D \leq 10^9$ .

58. An optical telecommunication system,  
comprising:

a laser diode,

a mount substrate on which said laser diode  
5 is mounted;

said laser diode comprising a surface-  
emission laser diode chip and comprising: an active  
layer of any of a layer containing Ga, In, N and As  
as major constituent elements thereof and a layer  
10 containing Ga, In and As as major constituent  
elements thereof, said active layer producing optical  
radiation with a laser oscillation wavelength of 1.1  
- 1.7  $\mu\text{m}$ ; and a cavity structure comprising a pair  
of reflectors provided above and below said active  
15 layer, each of said reflectors forming a  
semiconductor distributed Bragg reflector reflecting  
optical radiation having a wavelength of 1.1  $\mu\text{m}$  or  
more and comprising an alternate and repetitive  
stacking of a first material layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x$   
20  $\leq 1$ ) and a second material layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x$   
 $\leq 1$ ), wherein there is provided a hetero spike buffer  
layer between said first material layer and said  
second material layer, said hetero spike buffer layer  
having a refractive index intermediate between a  
25 refractive index of said first material layer and a

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refractive index of said second material layer, said hetero spike buffer layer having a composition represented as  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ) and a thickness of 20 - 50 nm,

5 wherein a difference of linear thermal expansion coefficient between said laser diode and said substrate is within  $2 \times 10^{-6}/\text{K}$ .

10

59. An optical telecommunication system, comprising:

a laser diode; and  
15 an optical fiber coupled optically to said laser diode,

said laser diode comprising a surface-emission laser diode chip and comprising: an active layer of any of a layer containing Ga, In, N and As as major constituent elements thereof and a layer  
20 containing Ga, In and As as major constituent elements thereof, said active layer producing optical radiation with a laser oscillation wavelength of 1.1 - 1.7  $\mu\text{m}$ ; and a cavity structure comprising a pair  
25 of reflectors provided above and below said active

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layer, each of said reflectors forming a semiconductor distributed Bragg reflector reflecting optical radiation having a wavelength of  $1.1\mu\text{m}$  or more and comprising an alternate and repetitive

5 stacking of a first material layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x \leq 1$ ) and a second material layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ), wherein there is provided a hetero spike buffer layer between said first material layer and said second material layer, said hetero spike buffer layer

10 having a refractive index intermediate between a refractive index of said first material layer and a refractive index of said second material layer, said hetero spike buffer layer having a composition represented as  $\text{Al}_z\text{Ga}_{1-z}\text{As}$  ( $0 \leq y < z < x \leq 1$ ) and a

15 thickness of 20 - 50 nm,

wherein said optical fiber is mechanically connected to said laser diode in the state that said optical fiber is urged in an axial direction thereof toward a light emitting part of said laser diode.

20

60. An optical telecommunication system,

25 comprising:

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a laser diode; and  
one of an optical fiber and an optical waveguide coupled optically to said laser diode,  
said laser diode comprising a surface-  
5 emission laser diode chip and comprising: an active layer of any of a layer containing Ga, In, N and As as major constituent elements thereof and a layer containing Ga, In and As as major constituent elements thereof, said active layer producing optical  
10 radiation with a laser oscillation wavelength of 1.1 - 1.7  $\mu\text{m}$ ; and a cavity structure comprising a pair of reflectors provided above and below said active layer, each of said reflectors forming a semiconductor distributed Bragg reflector reflecting  
15 optical radiation having a wavelength of 1.1  $\mu\text{m}$  or more and comprising an alternate and repetitive stacking of a first material layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x \leq 1$ ) and a second material layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ), wherein there is provided a hetero spike buffer  
20 layer between said first material layer and said second material layer, said hetero spike buffer layer having a refractive index intermediate between a refractive index of said first material layer and a refractive index of said second material layer, said  
25 hetero spike buffer layer having a composition

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represented as  $\text{Al}_z\text{Ga}_{1-z}\text{As}$  ( $0 \leq y < z < x \leq 1$ ) and a thickness of 20 - 50 nm,

said optical fiber or said optical waveguide having a core with a diameter  $X$ , said laser diode having an aperture  $d$  and an optical emission angle  $\theta$ ,

wherein there holds a relationship  
 $d + 2l \tan(\theta/2) \leq X$ ,

where  $l$  represents an optical path length from said laser diode to an edge of said optical fiber or optical waveguide.

15

61. An optical telecommunication system, comprising:

a laser diode; and

an optical waveguide coupled optically to said laser diode,

said laser diode comprising a surface-emission laser diode chip and comprising: an active layer of any of a layer containing Ga, In, N and As as major constituent elements thereof and a layer containing Ga, In and As as major constituent

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elements thereof, said active layer producing optical radiation with a laser oscillation wavelength of 1.1 - 1.7  $\mu\text{m}$ ; and a cavity structure comprising a pair of reflectors provided above and below said active layer, each of said reflectors forming a semiconductor distributed Bragg reflector reflecting optical radiation having a wavelength of 1.1  $\mu\text{m}$  or more and comprising an alternate and repetitive stacking of a first material layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x \leq 1$ ) and a second material layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ), wherein there is provided a hetero spike buffer layer between said first material layer and said second material layer, said hetero spike buffer layer having a refractive index intermediate between a refractive index of said first material layer and a refractive index of said second material layer, said hetero spike buffer layer having a composition represented as  $\text{Al}_z\text{Ga}_{1-z}\text{As}$  ( $0 \leq y < z < x \leq 1$ ) and a thickness of 20 - 50 nm,

wherein there holds a relationship

$$0.5 \leq F/d \leq 2$$

where d represents a diameter of a circle touching internally to an optical emission part of said laser diode and F represents a core diameter of said optical fiber.

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62. An optical telecommunication system,  
5 comprising:  
a laser diode; and  
an optical waveguide coupled optically to a  
laser chip,  
said laser diode comprising a surface-  
10 emission laser diode chip and comprising: an active  
layer of any of a layer containing Ga, In, N and As  
as major constituent elements thereof and a layer  
containing Ga, In and As as major constituent  
elements thereof, said active layer producing optical  
15 radiation with a laser oscillation wavelength of 1.1  
- 1.7  $\mu\text{m}$ ; and a cavity structure comprising a pair  
of reflectors provided above and below said active  
layer, each of said reflectors forming a  
semiconductor distributed Bragg reflector reflecting  
20 optical radiation having a wavelength of 1.1  $\mu\text{m}$  or  
more and comprising an alternate and repetitive  
stacking of a first material layer of  $\text{Al}_x\text{Ga}_{1-x}\text{As}$  ( $0 < x$   
 $\leq 1$ ) and a second material layer of  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x$   
 $\leq 1$ ), wherein there is provided a hetero spike buffer  
25 layer between said first material layer and said

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second material layer, said hetero spike buffer layer  
having a refractive index intermediate between a  
refractive index of said first material layer and a  
refractive index of said second material layer, said  
5 hetero spike buffer layer having a composition  
represented as  $\text{Al}_y\text{Ga}_{1-y}\text{As}$  ( $0 \leq y < x \leq 1$ ) and a  
thickness of 20 - 50 nm,

said laser diode including an optical  
emission part having an area  $S$  [ $\text{mm}^2$ ], said laser  
10 diode being driven with an operational voltage  $V$   
[volts],

wherein a parameter  $V/S$  falls in a range  
from 15000 to 30000.